6 EP19529

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to Electric Protective Systems

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to balanced voltage type of feeder protection systems comprising transformers associated with a feeder or feeders at the two ends of a section of said feeder or feeders, a closed loop pilot wire circuit extending between the ends of the section and including two transformer secondary windings, one secondary winding being associated with one end of said section and the other being associated with the other end of said section in such manner that voltages proportional to the currents in the feeder or feeders at the said ends of the section are induced in said pilot wire circuit in opposition to each other, and comparator means adjacent each end of the section and responsive to current flowing in said pilot wire circuit.

If no current is to flow in the pilot circuit during balanced conditions, it is essential that the transformer or each of the transformers at one end of the section be closely matched with the corresponding transformer or transformers at the other end of the section. This matching is very difficult to achieve and in practice current does flow in the circuit and causes mal-operation of the comparator means, usually a relay, unless precautions are taken to prevent it from doing so. The magnitude of this current is of course dependent upon the amount of mis-match between the transformers and in practice the transformers are chosen so that this amount is as small as possible consistent with the protective system being produced at a reasonable price. The other important factor determining the magnitude of the current is the self capacitance of the pilot wire circuit. Since this capacitance is inherent in the circuit itself it is difficult to control and it is therefore more convenient to reduce the response of the comparator means to it rather than to try and reduce it.

An object of the present invention is to provide a protective system in which the response to self capacitance currents is substantially eliminated without affecting the sensitivity of the system to normal fault current.

The invention relies on the fact that the normal fault current will produce in the pilot wire circuit a resistive rather than a capacitive current.

According to the present invention, in a feeder protection system of the type described and in which each of said comparator means is arranged to be operated in dependence upon current flowing in the closed loop circuit and to be restrained against operation in dependence upon the resultant voltage on the pilot wire circuit in the manner of an impedance type relay having a substantially circular resistance to reactance characteristic such that said comparator means is operated to indicate a fault on the protected section when the apparent impedance of said pilot wire circuit falls within the characteristic circle, each of said comparator means includes an impedance connected in parallel with said transformer secondary winding for measuring the resultant voltage in the closed loop and is so arranged that when the power flow in the pilot wire circuit is from the transformer secondary winding at the adjacent end the current to which the comparator means is responsive is the sum of the currents flowing around the closed loop and through said impedances to offset the resistance to reactance characteristic along the resistance axis and thereby to reduce the response of said comparator means to apparent capacitive impedance.

[*Price 3s. 6d.*]

Price 4s 6d.

In order that the invention may be readily understood an embodiment thereof will now be described by way of example with reference to the drawings accompanying the provisional specification in which Figures 1 to 4 show the basis from which the invention is derived, Figures 5 to 10 show circuit diagrams and graphs for explaining the invention and Figure 11 shows the complete circuit diagram for a system in accordance with the invention.

Figure 1 shows the basic circuit for the balanced voltage type of system; the circuit has been shown for single phase for simplicity. In this Figure, 1 is an alternating current feeder and matched current transformers 2 and 3 are provided in the feeder at the ends of the section.

The current transformers 2 and 3 are connected to the primary windings of matched summation transformer 4 or 5 whose secondary windings are connected in a closed loop pilot wire circuit 6 having comparator means in the form of two relays with operating windings 7 and 8 one at each end of the section and which are operated when current flows in the pilot wire circuit 6. The voltages induced across the secondary windings of the summation transformers 4 and 5 are arranged to be in opposition so that if the same current is flowing in the feeder at both ends of the section no current should flow in the pilot wire circuit 6. The circuit 6 has a self capacitance which is represented in the figure at 9 and resistance represented in the figure at 10 and 11.

Figure 2 shows only one half of the circuit of Figure 1 and the pilot impedance is represented by Z. In the arrangement shown in this figure a bias winding 12 is added in known manner to each of the relays of Figure 1 to impose a restraint torque on the relay proportional to the output of the associated summation transformer. This has the effect of increasing the relay operating current level when heavy current is flowing through the feeder such as under through fault conditions and thus improves the relay stability. Figure 2a shows a convenient representation of the biased relay as a balanced beam relay.

For a theoretical consideration of the operation of the relay it can be regarded as an impedance type relay which is balanced for only one value of impedance and this is when the ampere turns in the windings 7 and 12 are equal. This value of impedance can be found by plotting ampere turns against impedance for unit current through the impedance. Plotting impedance against ampere turns in the bias winding 12 per unit current through the impedance one gets a straight line passing through zero and if one converts this into three dimensions to split up the impedance into its resistive and reactive components one gets a cone as shown in Figure 3; it will be appreciated that the bias winding 12 is not sensitive to the type of impedance in the pilot wire circuit, i.e. whether it is resistive or capacitive. The ampere turns in the operating winding 7 are constant for unit current flow through the impedance and thus cut the cone in a circle as is shown in Figure 4. It will be appreciated that the circle of intersection gives the value of impedance at which the ampere turns balance and is independent of the actual voltage and current in the pilot wire circuit. For operation of the relay the impedance must not fall outside this circle since if it is greater, the ampere turns in the bias winding 12 will restrain the relay against operation. It will be appreciated that the relay is sensitive to the impedance but cannot discriminate between resistive and capacitive impedance. Under through fault conditions the impedance is governed mainly by the pilot capacitance. Mis-match of the transformer and transient current transformer saturation decreases the impedance seen by the relay.

Figure 5 shows how the circuit is slightly modified in accordance with the invention but with very important advantages. The modification is that the operating winding 7 is positioned differently relatively to the bias winding 12. Again the same cone is produced for ampere turns per unit current plotted against impedance for the bias winding 12 but the operating winding 7 now takes into account the impedance of the bias winding 12 since it carries the small current which passes through the bias winding 12 as well as the current passing through the impedance when the power flow is from the adjacent secondary winding of transformer 4. Thus plotting ampere turns per unit current for the operating winding 7 against impedance a cone is again produced which if the impedance producing the small current flowing through the bias winding is purely resistive is displaced along the resistance axis from the origin. By making the slope for the operating winding 7 less than the slope for the bias winding 12 by suitably arranging the inductance values of the windings 7 and 12, the cones intersect as can be appreciated from Figure 6 which shows impedance Z plotted against ampere turns per unit current flowing through the impedance. Thus the characteristic reactance to resistance circle is shown at 13 in Figure 7 and it will be seen that the origin is displaced from the centre of the operating circle so that the response to capacitive impedance is reduced. It will be seen that if the capacitive impedance exceeds the value OA then the relay is not operated for this value of current whereas the resistance can have a value OB before the relay is prevented from operation. Now in the arrangement shown in Figure 2, for a response to this value of resistance the response to capacitance would be OC and therefore the response to capacitive current has decreased by AC.

Under through fault conditions the impedance seen by the relay is governed by the pilot capacitance and has a phase angle ϕ (see Figure 7). It must of course lie well outside the relay circle characteristic. With an internal fault the impedance seen by the relay with current fed from one end only, or from both ends are represented by OD and OE respectively. It will be seen that these impedances are largely resistive and lead the capacitative impedance seen on through faults by an angle approaching 90°.

Figure 8 shows the circuit diagram of a system incorporating the features shown in the previous circuit diagrams. This figure indicates a fault at the left hand end of the system and the arrows show the power flow indicating that transformer 4 is the source of power for current flow in the pilot wire circuit. In view of what has been said previously it will be appreciated that under these conditions the relay on the left will have the operating characteristics of the circle 13 in Figure 7 since the operating winding 7 carries the current flowing in the bias winding 12 but the operating winding 8 will have a characteristic as shown in Figure 4 and representing this on Figure 7 is shown as arc 15 centred at O.

It is desirable that both relays operate at about the same level of fault current when a feeder fault is fed from one end only such as is shown in Figure 8. In order to proportion the relay settings and pilot values to the most suitable level a study has been made and this has shown that with pilots of loop resistance of 750 ohms the resistance "reach" i.e. the distance OB on Figure 7 should be set to about 2400 ohms. While this overcomes the problem of both relays operating at the same level it does not reduce the circle area to the minimum permissible. The lower the reach, i.e. the sensitivity consistent with reliable response to internal faults, the greater will be stability of the protection under heavy through fault conditions when "mis-match" may produce differences in the phase angle and magnitude of the summation transformer output from the two ends. Figure 9 shows how the reach may be reduced under heavy through fault conditions by inserting a non-linear resistor in with a section of the resistance of the bias winding circuit and Figure 10 shows the effect of this, the inner arc showing the reduced reach under heavy through fault conditions and the outer arc showing the reach under average fault levels. The effect of the non-linear resistance is to vary the biasing force non-linearly with voltage across the winding. At low voltages the non-linear resistor carries little or no current but with increasing voltages its resistance is reduced and the total resistance in the circuit 6 of the bias winding 12 is reduced. Thus the effect is to vary the slope of the cone for ampere turns against impedance of the bias winding 12 and this gives the overall effect shown in Figure 10.

So far only a system using an alternating current relay has been considered. In practice in view of the limited operating power that can be transmitted over long pilots with limited pilot volts a sensitive relay is required and it may be preferable to use a direct current device. Figure 11 therefore shows the principles of the previous alternating current systems using a direct current device. As far as possible the reference numerals used in the previous figures have again been used.

In Figure 11 a protective system for a three phase feeder system is shown, the current transformers 2 and 3 being associated with further current transformers 16 and 17 and 18 and 19 provided in the other feeders. The current transformers are connected to the summation transformers 4 and 5 as shown. The summation transformers 4 and 5 serve to isolate the pilots from the current transformers. It will be noted that both sets of current transformers are earthed and the pilot circuit is not earthed. The non-linear resistances 20 and 21 across the secondary windings of the current transformers limit the peak pilot voltage to a suitable level. Circuit breakers 22 and 23 are provided in the feeders and are operated by the pilot circuit when there are fault conditions on the section between the circuit breakers.

In the system shown in Figure 11, the relays at each end of the system are indicated at 24 and 25 and have a single winding wired in a comparator circuit indicated by 26 for the left hand relay and 27 for the right hand relay. Each comparator circuit comprises transformers 31 and 32 having primary and secondary windings 33 and 30 respectively, a pair of full wave rectifiers 28 and 29, the ones 28, being connected in series with the secondary windings of the summation transformers 4 and 5 and the others, 29 being connected across the secondary windings 30. The primary windings 33 are connected in parallel with the secondary windings of the summation transformers 4 and 5 and are positioned similarly to the bias windings 12 and 14 of Figures 5 to 8 so that they measure the voltage on the pilot wire circuit and their impedance affects the response of the relays 24 and 25 in that the current flowing through each of the rectifiers 28 when the power flow is from the adjacent end includes the current flowing through the windings 33 so that the characteristic resistance to reactance circle is displaced along the resistance axis as in the arrangement of Figures 5 to 8.

A non-linear resistance 15 is connected in the right hand side of the circuit in similar manner to that connected in the left hand side of the circuit.

It will no doubt be appreciated that this circuit is the equivalent of the one previously

described but using a direct current device instead of an alternating current one.

The relay used in the circuit must be sensitive but not be too fast in response otherwise spurious operation will arise. One type of relay which may be used is a moving coil relay which may be damped to suit the requirements. Another possible alternative is to use a transistorised amplitude comparator.

WHAT WE CLAIM IS:—

1. A balanced voltage type of feeder protection system comprising transformers associated with a feeder or feeders at the two ends of a section of said feeder or feeders, a closed loop pilot wire circuit extending between the ends of the section and including two transformer secondary windings, one secondary winding being associated with one end of said section and the other being associated with the other end of said section in such manner that voltages proportional to the currents in the feeder or feeders at the said ends of the section are induced in said pilot wire circuit in opposition to each other, and comparator means adjacent each end of the section, each of said comparator means being arranged to be operated in dependence upon the current flowing in the closed loop circuit and to be restrained against operation in dependence upon the resultant voltage on the pilot wire circuit in the manner of an impedance type relay having a substantially circular resistance to reactance characteristic such that said comparator means is operated to indicate a fault on the protected section when the apparent impedance of said pilot wire circuit falls within the characteristic circle, wherein each of said comparator means includes an impedance connected in parallel with said transformer secondary windings for measuring the resultant voltage in the closed loop and is so arranged that when the power flow in the pilot wire circuit is from the transformer secondary winding at the adjacent end, the current to which the comparator means is responsivte is the sum of the currents flowing around the closed loop and through said impedances, to offset the resistance to reactance characteristic along the resistance axis and thereby to reduce the response of said comparator means to apparent capacitive impedance.

2. A balanced voltage type of feeder protection system as claimed in Claim 1, wherein the comparator means each comprise an alternating current electromagnetic relay and said impedance constitutes a bias winding of said relay.

3. A balanced voltage type of feeder protection system as claimed in Claim 1, wherein the comparator means each comprise a direct current relay, rectifying means and a transformer whose secondary winding is connected to said relay through said rectifying means and whose primary winding constitutes said impedance.

4. A balanced voltage type of feeder protection as claimed in any one of Claims 1 to 3 wherein a non-linear resistance is in series with each of said impedances, to reduce the sensitivity of the comparator means as through fault current becomes higher.

5. A balanced voltage type of feeder protection system as claimed in any one of the preceding claims, wherein non-linear resistances are connected in parallel with said secondary windings in the pilot circuit for limiting the peak voltages on the comparator means.

6. A balanced voltage type of feeder protection system substantially as hereinbefore described by way of example with reference to and as shown in Figures 5 to 10 or Figure 11 of the drawings accompanying the provisional specification.

For the Applicants:
F. S. PEACHEY,
Chartered Patent Agent.

PROVISIONAL SPECIFICATION

Improvements in or relating to Electric Protective Systems

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British Company, do hereby declare this invention to be described in the following statement:—

The present invention relates to balanced voltage type of feeder protection systems comprising transformers associated with a feeder or feeders at the two ends of a section of said feeder or feeders, a closed loop pilot wire circuit including two transformer secondary windings, one secondary winding being associated with end of said section and the other being associated with the other end of said section in such manner that voltage proportional to the currents in the feeder or feeders at the said ends of the section are induced in said pilot wire circuit in opposition to each other, and comparator means operable due to current of a predetermined value in said pilot wire circuit.

If no current is to flow in the pilot circuit during balanced conditions, it is essential that the transformer or each of the transformers at one end of the section be closely matched with the corresponding transformer or transformers at the other end of the section. This matching is very difficult to achieve and in practice current does flow in the circuit and causes mal-operation of the comparator means, usually a relay, unless precautions are taken to prevent it from doing so. The magnitude of this current is of course dependent upon the amount of mis-match between the transformers

and in practice the transformers are chosen so that this amount is as small as possible consistent with the protective system being produced at a reasonable price. The other important factor determining the magnitude of the current is the self capacitance of the pilot wire circuit. Since this capacitance is inherent of the circuit itself it is difficult to control and it is therefore more convenient to reduce the response of the comparator means to it rather than to try and reduce it.

An object of the present invention is to provide a protective system in which the response to self capacitance currents is substantially eliminated without effecting the sensitivity of the system to normal fault current.

The invention relies on the fact that the normal fault current will be resistive rather than capacitive.

According to the present invention, in a feeder protection system of the type described, an inductive winding is connected in parallel with said secondary transformer windings from which inductive winding is arranged to be derived a voltage or magneto motive force for biasing said comparator means against operation, and said comparator means is connected to be responsive to the sum of the current flowing in said pilot wire circuit due to the voltage difference in said transformer secondary windings and the current taken by said inductive winding so that said comparator means is less responsive to capacitive currents than to resistive currents in said pilot wire circuit.

In order that the invention may be readily understood an embodiment thereof will now be described by way of example with reference to the accompanying drawings in which Figures 1 to 10 show circuit diagrams and graphs for explaining the invention and Figure 11 shows the complete circuit diagram for a system in accordance with the invention.

Figure 1 shows the basic circuit for the balanced voltage type of system; the circuit has been shown single phase for simplicity. In this figure, 1 is an alternating current feeder and matched current transformers 2 and 3 are provided in the feeder at the ends of the section.

The current transformers 2 and 3 are connected to the primary windings of matched summation transformer 4 or 5 whose secondary windings are connected in a closed loop pilot wire circuit 6 having two relays with operating windings 7 and 8 of one at each end of the section and which are operated when current flows in the pilot wire circuit 6. The voltages induced across the secondary windings of the summation transformers 4 and 5 are arranged in opposition so that if the same current is flowing in the feeder at both ends of the section no current should flow in the pilot wire circuit 6. The circuit 6 has a self capacitance which is represented in the figure at 9 and resistance represented in the figure at 10 and 11.

Figure 2 shows only one half of the circuit of Figure 1 and the pilot impedance is represented by Z. In the arrangement shown in this figure a bias winding 12 is added to each of the relays of Figure 1 to impose a restraint torque on the relay proportional to the output of the summation transformer 4. This has the effect of increasing the relay operate current level when heavy current is flowing through the feeder such as under through fault conditions and thus improves the relay stability. Figure 2a shows a convenient representation of the biased relay as a balanced beam relay.

For a theoretical consideration of the operation of the relay if one plots impedance against ampere turns per unit current in the bias winding 12 one gets a straight line passing through zero and if one converts this into three dimensions to split up the impedance into its resistive and reactive components one gets a cone as shown in Figure 3; it will be appreciated that the bias winding 12 is not sensitive to the type of impedance in the pilot wire circuit, i.e. whether it is resistive or capacitive, the ampere turns in the operating winding 7 are constant and thus cut the cone in a circle as is shown in Figure 4. It will be appreciated that the circle of intersection in independent of the voltage and current in the pilot wire circuit. For operation of the relay the impedance must not fall outside this circle since if it is the greater ampere turns in the bias winding 12 will restrain the relay against operation. It will be appreciated that the relay is sensitive to the impedance but cannot discriminate between resistive and capacitive impedance.

Figure 5 shows a slightly modified circuit diagram in which the operating winding 7 is positioned differently relatively to the bias winding 12. Again, the same cone is produced for ampere turns per unit current plotted against impedance for the bias winding 12 but the operating winding 7 now carries the small current which passes through the bias winding 12 as well as the current passing through the impedance. Thus plotting ampere turns per unit current for the operating winding 7 against impedance a cone is again produced which if the impedance producing the small current flowing through the bias winding is purely resistive is displaced along the resistance axis from the origin. By making the slope for the operating winding 7 less than the slope for the bias winding 12 by suitably arranging the inductance values of the windings 7 and 12, the cones intersect as can be appreciated from Figure 6 which shows impedance 2 plotted against ampere turns per unit current. Thus the circle of operation for a given current is shown at 13 in Figure 7 and it will be seen that the origin

is displaced from the centre of the operating circle so that the response to capacitive current is reduced. It will be seen that if the capacitive impedance exceeds the value OA then the relay is not operated for this value of current whereas the resistance can have a value OB before the relay is prevented from operation. Now in the arrangement shown in Figure 2, for a response to this value of resistance the response to capacitance would be OC and therefore the response to capacitive current has decreased by AC.

Under through fault conditions the impedance seen by the relay is governed by the pilot capacitance and has a phase angle (see Figure 7). It must of course lie well outside the relay circle characteristic. With an internal fault the impedance seen by the relay with current fed from one end only, or from both ends are represented by OD and OE respectively. It will be seen that these impedances are largely resistive and lead the capacitative impedance seen on through faults by an angle approaching 90°.

Figure 8 shows the circuit diagram of a system incorporating the features shown in the previous circuit diagrams. This figure indicates a fault at the left hand end of the system and the arrows show the current flow. In view of what has been said previously it will be appreciated that under these conditions the relay on the left will have the operating characteristics of the circle 13 in Figure 7 since the operating winding 7 carries the current flowing in the bias winding 12 but the operating winding 8 will have a characteristic as shown in Figure 4 and representing this on Figure 7 is shown as arc 15 centred at O.

It is desirable that both relays operate at about the same level of fault current when a feeder fault is fed from one end only such as is shown in Figure 8. In order to proportion the relay settings and pilot values to the most suitable level a study has been made and this has shown that with pilots of loop resistance of 750 ohms the resistance "reach" i.e. the distance OB on Figure 7 should be set to about 2400 ohms. While this overcomes the problem of both relays operating at the same level it does not reduce the circle area to the minimum permissible. The smaller the reach consistent with reliable response to internal faults, the greater will be stability of the protection under heavy through fault conditions when "mis-match" may produce differences in the phase angle and magnitude of the summation transformer output from the two ends. Figure 9 shows how the reach may be reduced under heavy fault conditions by inserting a non-linear resistor in with a section of the resistance of bias winding circuit and Figure 10 shows the effect of this the inner arc showing the reduced reach under heavy through fault conditions and the outer arc showing the reach under average fault levels. The effect of the non-linear resistance is to vary the biasing force non-linearly with voltage across the winding. At low voltages the non-linearly resistor carries little or no current but with increasing voltages its resistance is reduced and the total resistance 6 in the circuit of the bias winding 12 is reduced. Thus the effect is to vary the slope of the cone for ampere turns against impedance of the bias winding 12 and this gives the overall effect shown in Figure 10.

So far an alternating currrent system only has been considered. In practice in view of the limited operating power that can be transmitted over long pilots with limited pilot volts a sensitive relay is required and it becomes necessary to use a direct current device. Figure 11 therefore shows the principles of the previous alternating current systems used in a direct current system. As far as possible the reference numerals used in the previous figures have again been used.

In Figure 11 a protective system for a three phase feeder system is shown, the current transformers 2 and 3 being connected to further current transformers 16 and 17 and 18 and 19 provided in the other feeders. The current transformers are connected to the summation transformers 4 and 5 as shown. With this arrangement the summation transformers serve to isolate the pilots from the current transormers. It will be noted that both sets of current transformers are earthed and the pilot circuit is not earthed. The non-linear resistance 20 and 21 across the secondary windings of the current transformers limit the peak pilot voltage to a suitable level. Circuit breakers 22 and 23 are provided in the feeders and are operated by the pilot circuit when there are fault conditions on the section between the circuit breakers.

In the system shown in Figure 11, the relays at each end of the system are indicated at 24 and 25 and have a single winding wired in a comparator circuit indicated by 26 for the left hand relay and 27 for the right hand relay. Each comparator circuit comprises a pair of full wave rectifiers 28 and 29, the ones 28, being connected in series with the secondary windings of the summation transformers 4 and 5 and the other, 29, being connected in parallel with the secondary windings of the summation transformers 4 and 5. A non-linear resistance 15 is connected in the right hand side of the circuit in similar manner to that connected in the left hand side of the circuit.

It will no doubt be appreciated that this circuit is the equivalent of the alternating current one previously discussed.

The relay used in the circuit must be sensitive but not be too fast in response otherwise spurious operation will arise. One type of relay which may be used is a moving coil relay which may be damped to suit

the requirements. Another possible alternative is to use a transistorised amplitude comparator.

For the Applicants:
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Published at the Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained

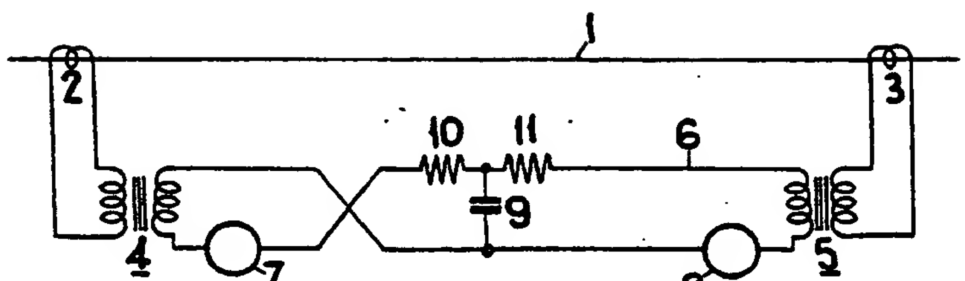


Fig.1

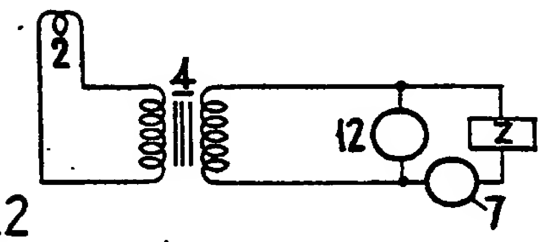


Fig.2

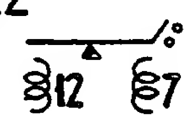


Fig.2a

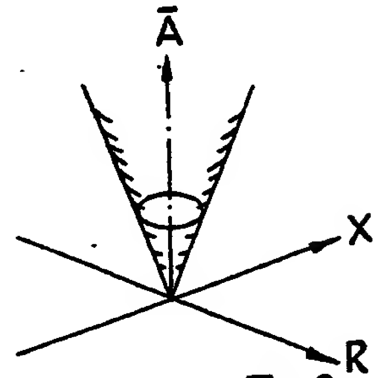


Fig.3

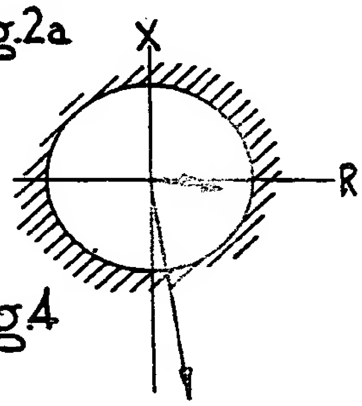


Fig.4

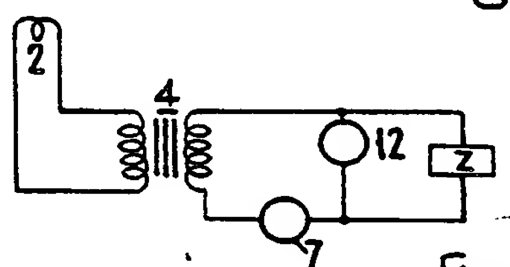


Fig.5

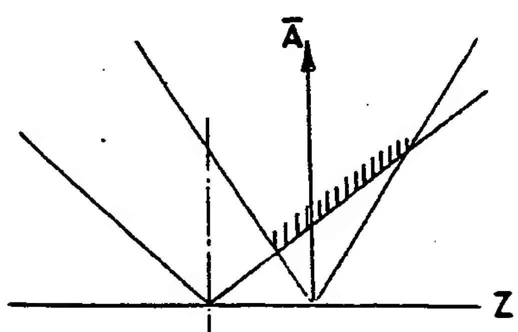


Fig.6

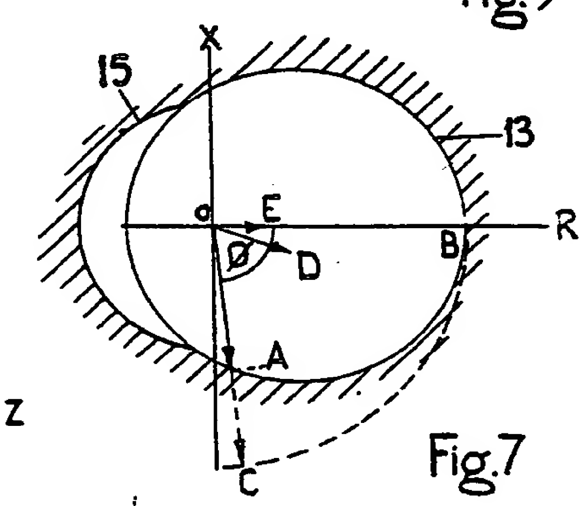
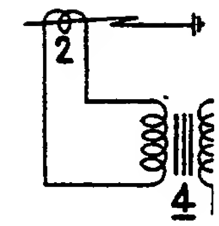
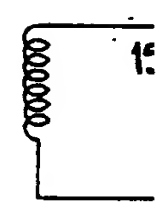


Fig.7





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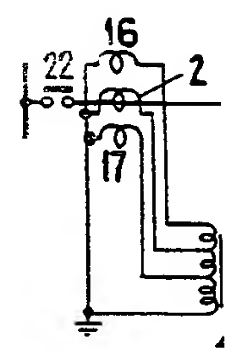
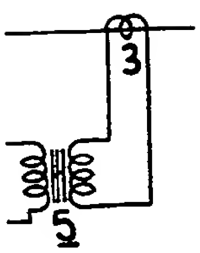


865775 PROVISIONAL SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2



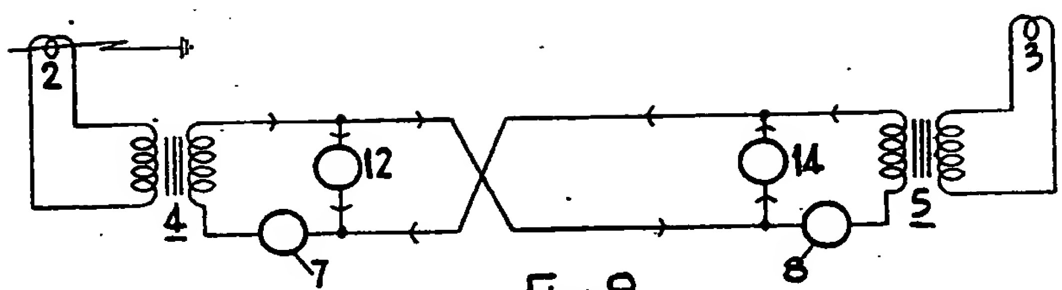


Fig.8

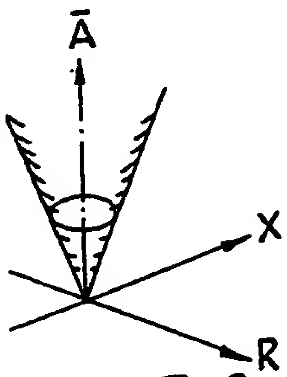


Fig.3

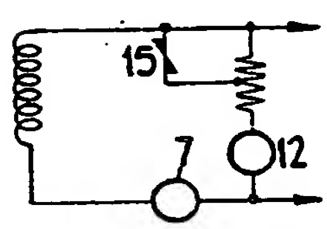


Fig.9

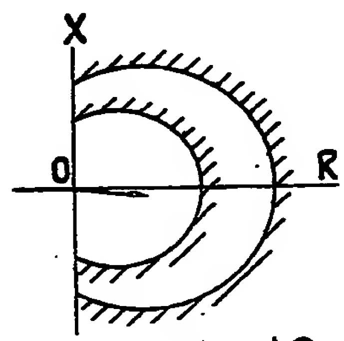


Fig.10

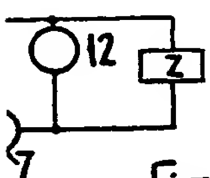


Fig.5

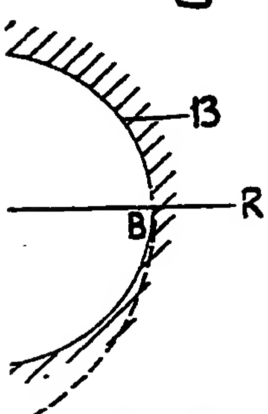


Fig.7

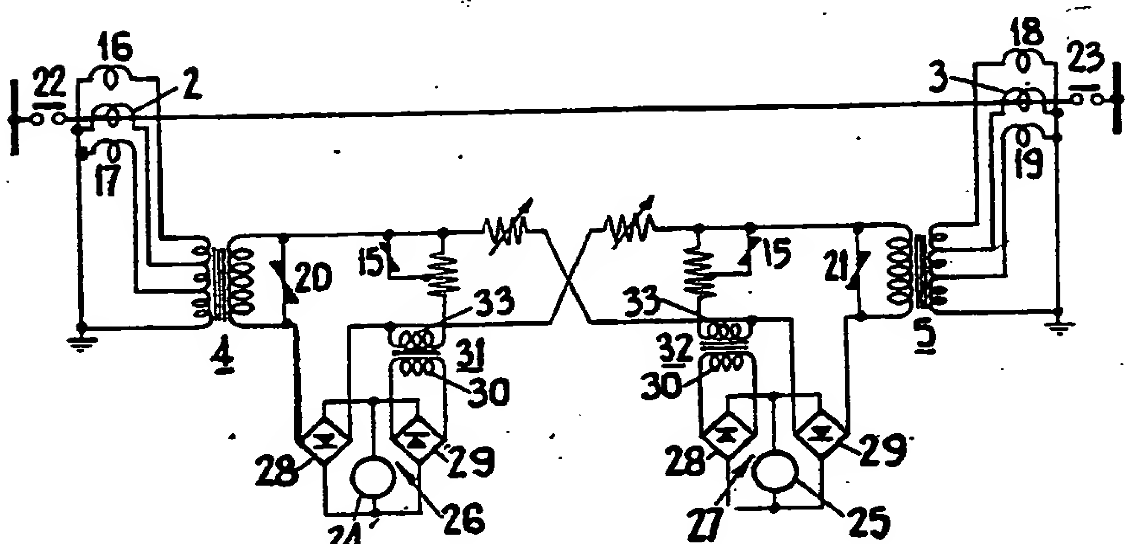


Fig.11

865775 PROVISIONAL SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheets 1 & 2

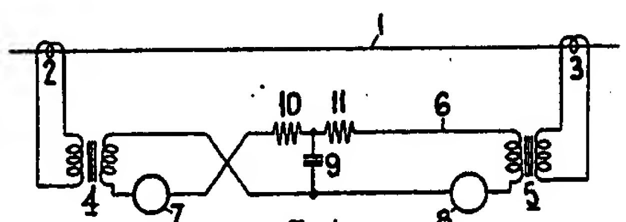


Fig.1

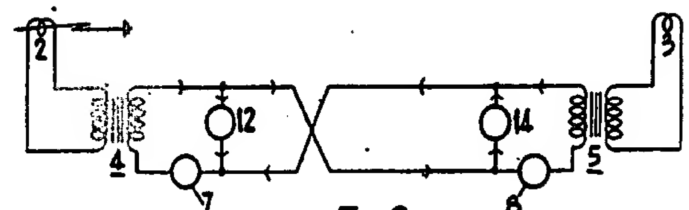


Fig.8

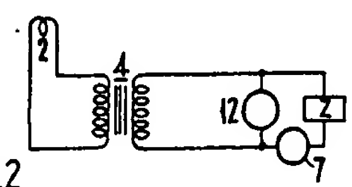


Fig.2

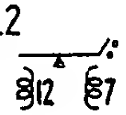


Fig.2a

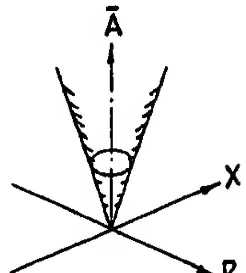


Fig.3

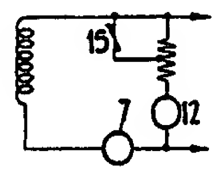


Fig.9

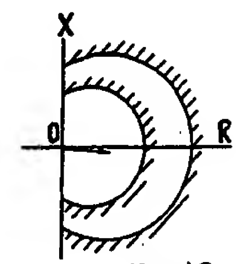


Fig.10

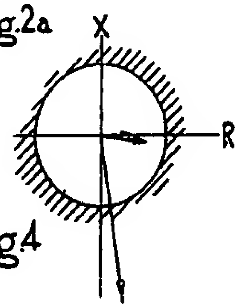


Fig.4

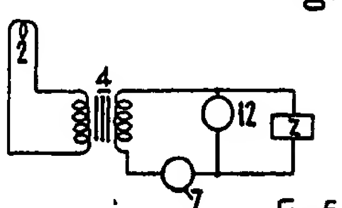


Fig.5

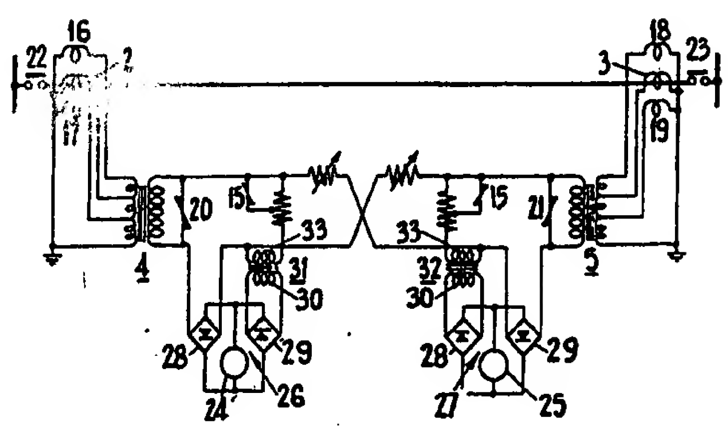


Fig.11

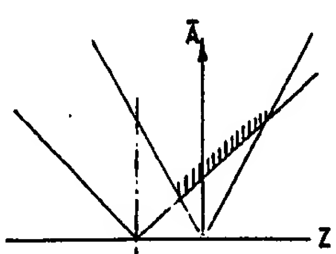


Fig.6

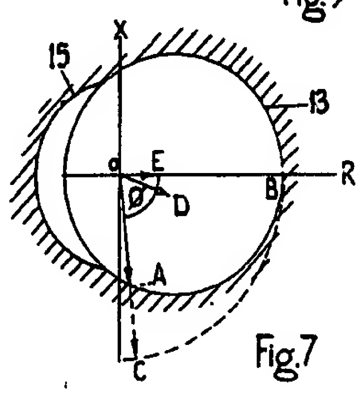


Fig.7